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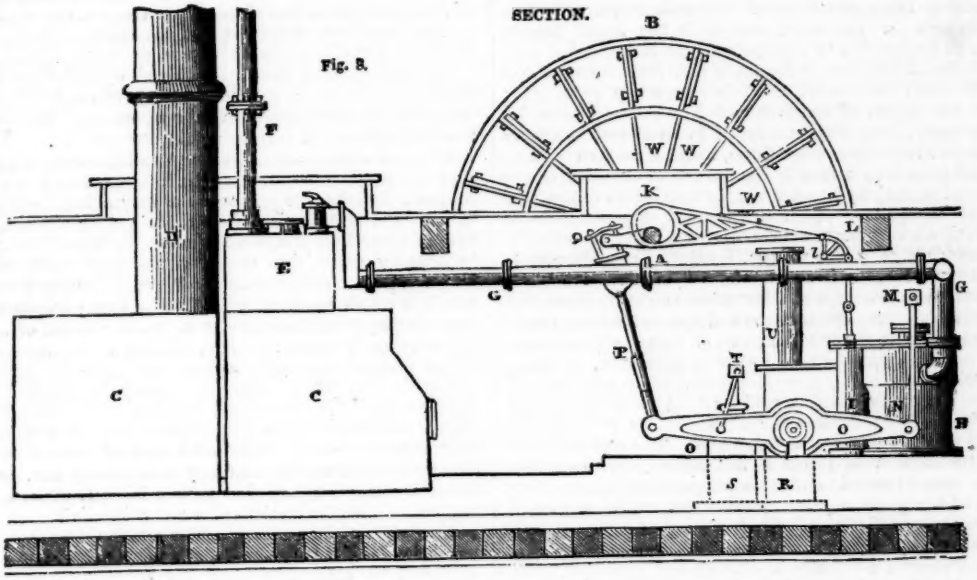
A BRIEF HISTORY OF NAVIGATION. PART VI.

CONCLUDED

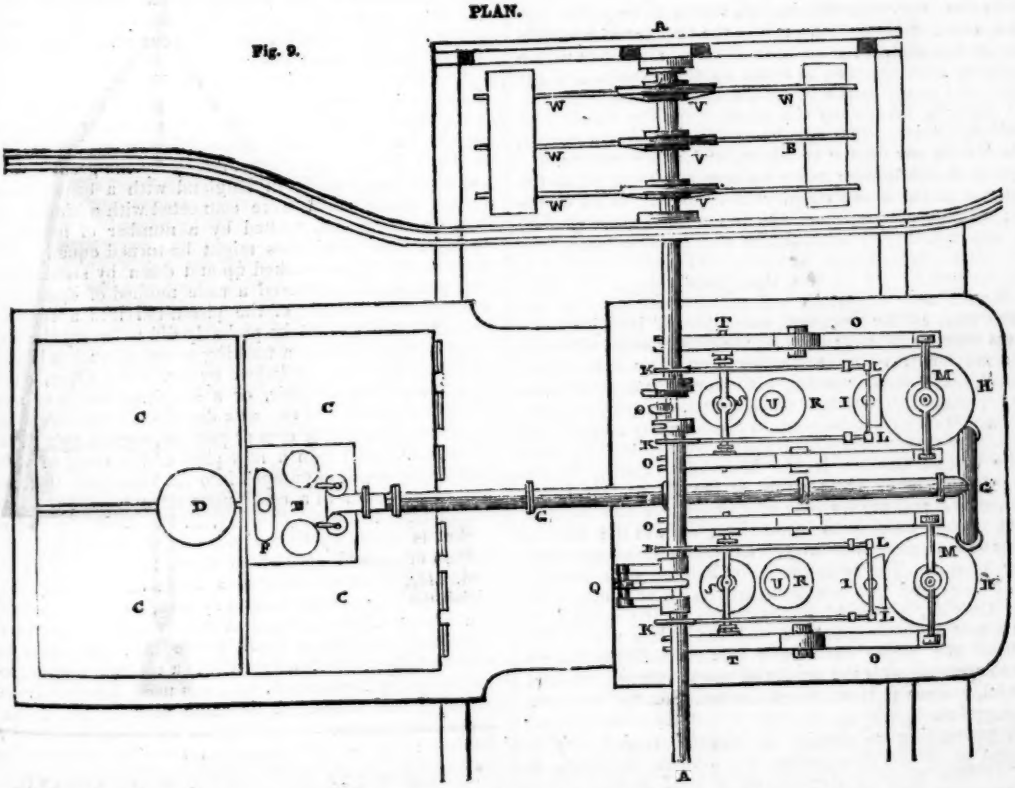
SECTION.

Fig. 8.



PLAN.

Fig. 9.



SECTION AND PLAN OF THE WORKING PARTS OF A STEAM-BOAT.

ON STEAM NAVIGATION.

Soon shall thy arm, unconquer'd Steam! afar
Drag the slow barge, or drive the rapid car:
Or, on wide-waving wings expanded bear
The flying chariot through the fields of air.—DARWIN.

THE Steam-Engine is one of the grandest inventions of modern times; not only on account of its gigantic force as a *prime* mover, but also on account of what may be termed its flexibility; for there is, perhaps, scarcely an art or trade, wherein machines, whether of a simple or complicated character, require to be set in motion, but can receive that motion from the steam-engine in a far more perfect and effective manner than through the agency of any other force. But none of the applications of this noble engine surpass, in usefulness or important results to the great human family, its application to Navigation. It has afforded new and wonderful facilities to the trade and intercourse of the civilized world in general, and this country in particular; and all our means of communication, whether by sea, by river or canal, have been multiplied to an almost indefinite extent. "From the earliest times, (says a modern writer,) mankind have been baffled by the uncertain elements of the winds and waves: by these a barrier was raised to the progress of navigation, which the boasted improvements of modern times were never able to overcome; and the proverbial uncertainty of a sea voyage, continued accordingly, to be ranked among the irremediable evils of life. Hence it was, that when a voyage of a few miles might be protracted to several days, those great rivers and inlets of the sea, which penetrate far into the land, instead of being of unrivalled utility to commerce, formed rather a drawback, in many cases, to our internal communications; while with respect to rivers, no attempt could be made, with the least advantage, to navigate them against the stream. We possessed no power that could accomplish this object. The use of a river, as an instrument of internal intercourse, was, in consequence, much limited; and no craft were ever found to ply on any of the great streams, because they could only make their way in one direction. They were useless, except for this single purpose; and in all countries the water communications were in a manner mutilated, and imperfect."

In illustration of these remarks, it may be instanced that on the great river Mississippi, which flows at the rate of five or six miles an hour, it was the practice of a certain class of boatmen, who brought down the produce of the interior of New Orleans, to break up their boats, sell the timber, and return home by a slow and toilsome land-journey; since a voyage up the river, from New Orleans to Pittsburgh, (about 2000 miles,) could scarcely be accomplished, with any degree of labour, under four months.

But now, Navigation needs no longer be impeded by the uncertain action of the wind, or the opposing effort of the tide: we have a new power, which is perfectly manageable, and acts in both directions, almost with equal efficacy. The four month's voyage from New Orleans to Pittsburgh is now performed with ease in less than twenty days. Voyages which were once uncertain and tedious, can now be performed with all the ease and expedition of land-journeys. Rivers which were once solitary, are now crowded with vessels: the small towns and villages on their banks have grown up into cities teeming with commercial abundance. The opposing waters cannot resist the passage of the steam-boat, which is now to be seen on almost every river in the world. The steam-boat plies regularly on almost every river in the United States: it has long been known on the Ganges, and other great rivers of the East. The rivers, lakes, inlets, and narrow seas of Europe, are the constant resort of this ubiquitous locomotive; and, in the internal navigation of our own country, it has taken the place of most other vessels. The intercourse of Britain with Ireland, with France and the continent generally, and now even with America, is carried on by means of the steam-boat. The aspect of many countries, and the habits and intelligence of the people have been vastly ameliorated by the free intercourse with the agents of moral, intellectual, commercial, and social improvement, which Steam-Navigation has supplied.

In proceeding to supply the general reader with an account of Steam-Navigation, we propose to divide our subject into three parts:—*First*, a brief history of the origin, rise, and progress of Steam-Navigation. *Secondly*, a popular view of the wondrous agent which acts as the prime mover of the Steam-boat. And *Thirdly*, a detailed account of the application of the Steam-engine to the purposes of Navigation.

I. The idea of propelling vessels by paddles fixed to the circumference of a wheel is by no means modern. This mode, as a substitute for oars, is mentioned in a curious work, *De re militari*, by Valturius of Rimini. It was first printed by John of Verona in 1472, and is a very fine and ancient specimen of typography and wood engraving. One of the machines described in this book is a flat-bottomed boat, which might be impelled across a river by vanes of pitched sail-cloth, fixed to axles and turned round by men, by means of winches or cranks. These vanes, or paddles, dipped into the water, and when they were moved through that fluid, its reaction forced the boat in the contrary direction. They served as fins to fishes, or as wings to birds and insects; and the author of the above treatise states that one of these paddle-wheels was equal in efficacy to twelve oars; but then it would probably require as much force to move it, so that nothing would be gained by substituting the paddle for the oars: on the contrary, where human force was used, the oars would have the advantage. It is obvious that some modes of employing the strength of a man or an animal are much more advantageous than others, because they allow more of that strength to be profitably turned to account; besides, the best mode of employing the strength of one kind of animal is often the worst for another. For example, the force of a horse is employed most economically in drawing, while that is one of the very worst ways of employing a man's strength. Now, although turning a winch or crank has been proved to be a very advantageous way for employing human power, yet the action of rowing is undoubtedly better; in fact, rowing is the most economical method in which a man can possibly exert his strength; but when any other power is employed, the paddles have the advantage, because they simply require animal or mechanical power, whereas rowing requires not only force but skill. This advantage of paddles is more especially remarkable when any inanimate power, such as steam is used; for then that motion is best, which is most simple. Now the motion of an oar in rowing is rather complicated, while a mere circular rotation, like that of the paddle-wheels, is very simple, and is, perhaps, more easily produced by machinery than any other kind of motion. One advantage of the paddles, when human force is employed, is that any number of persons can work together at the crank of a paddle, while an oar cannot conveniently be managed by more than one.

The first proposition to drive vessels against the wind by the force of steam, was made by Papin, a Frenchman, who is regarded by his countrymen as the inventor of the steam-engine, and he certainly did contrive an engine worked by steam. He had been much struck by the great success of an experiment made in England with a boat driven by paddle-wheels, which were connected with a kind of windlass on the vessel, turned by a number of horses. He thought that the paddles might be turned equally well by the rod of a piston worked up and down by steam, and for this purpose he contrived a rude method of changing the reciprocating motion of the piston-rod into a continuous circular rotation; but he probably did not carry the project further than making a working model of such a boat. In 1730, a work was published by Dr. John Allen, entitled, *Specimina Ichnographia, or a brief Narrative of several New Inventions.* It contains descriptions of several plans for driving vessels by oars or paddles, worked by a windlass or capstan; and also a new plan of his own, in which a quantity of water is pumped into the vessel and then forced out at the stern in a continuous stream,—the re-action of which forced the vessel along, in the same manner as a rocket is forced up by the re-action of the air against the stream of ignited substances which rush out at its lower end. Dr. Allen constructed a large boat of this kind, in which the pumps were worked by men, but he suggests that the labour might be more advantageously performed by a steam-engine. Some years before this, the atmospheric steam-engine had been brought to a considerable degree of perfection by Newcomen, and was used for the purpose of draining coal-works. This same plan of Dr. Allen for propelling vessels, by sucking in water at the head and forcing it out at the stern, has since been revived and patented by several individuals.

In 1737, a tract was published by Jonathan Hulls, entitled, *A Description and Draught of a new Invented Machine for carrying Vessels or Ships out of any Harbour, Port, or River, against Wind or Tide, or in a Calm,*

Printed for the Author, and sold, price Sixpence, at the pamphlet shops of London and Westminster. This is generally considered as the first attempt at steam-navigation. The following is an extract from the treatise, and shows the principle on which his engine acted. "In some convenient part of the tow-boat, there is placed a vessel about two-thirds full of water, with the top close shut; this vessel being kept boiling rarifies the water into steam; which, being conveyed through a large pipe into a cylindrical vessel, and there condensed, makes a vacuum, which causes the weight of the atmosphere to press on the vessel, and so presses down a piston that is fitted into this cylindrical vessel, in the same manner as in Mr. Newcomen's engine, with which he raises water by fire. It has been demonstrated, that when the air is driven out of a vessel of thirty inches diameter, the atmosphere will press on it to the weight of four tons, sixteen hundred weight, and upwards: when proper instruments for this work are applied to it, it must drive a vessel with great force." If Hulls did not make the first steam-boat, he certainly first proposed the means of turning paddle-wheels by the force of steam, and exactly in the manner now employed, namely, by means of the crank, a most simple and beautiful contrivance for converting a reciprocating motion into a circular one.

No other attempt at steam-navigation appears to have been made for a long time, until the stationary land steam-engine had been improved, and brought almost to perfection, by Watt, and had been applied to the moving of every kind of machinery for manufacturing purposes.

The next person who turned his attention to the subject was a M. Perier, who, in 1775, tried a small boat, or rather model, on the Seine; but though it succeeded, its motion was very slow, on account of the small power of the engine. He did not, however, pursue the attempt.

In 1781, the Marquis de Jouffray made several experiments on the Saone, at Lyons, with a boat no less than 140 feet long. He was not very successful, owing to various accidents which occurred, but his investigation was soon stopped by the Revolution, which drove him from his country. The subject was now taken up nearly at the same time in Italy by M. Serratti, in Scotland by Mr. Miller, and in America by two rival competitors, James Rumsey of Virginia, and John Fitch of Philadelphia. Mr. Miller had been induced to make the attempt by seeing a model of a steam-carriage made by William Symington. It struck him that the paddle-wheels of a boat might be turned in the same manner as the wheels of a carriage, and he accordingly directed Symington to construct a similar engine to work a boat. This having succeeded very well on a small scale, he tried a much larger boat on the Forth and Clyde canal, but it was found that the disturbance of the water occasioned by the paddles destroyed the banks of the canal. Mr. Rumsey's first steam-boat was about fifty feet in length, but the engine occupied a very small space, the boiler holding only five gallons of water, and the daily consumption of fuel was only from four to six bushels of coals. Nevertheless, the boat moved at the rate of three or four miles an hour when loaded with three tons, in addition to the engine which weighed one-third of a ton; it worked a large pump by which water was drawn in at the bow and forced out at the stern, as in Dr. Allen's proposition. His next project was to move the boat by long poles, pushed against the bottom of the river by the power of the engine. Fitch's boat was propelled by paddles like the modern steam-boat, but there was a great deal of rivalry between these Americans; the invention finally proved the ruin of Fitch, and he at last abandoned the undertaking. It was afterwards taken up by a great number of Americans and others, but no attempts can be considered completely successful till the time of the celebrated Robert Fulton, who is commonly considered as the father of steam-navigation. He was born in the year 1765 in the town of Little Britain, county of Lancaster, state of Pensylvania, and showed a taste for mechanics at an early age; he got his livelihood by portrait-painting, and lived several years in London with West, who patronized him. After this he lived at Exeter, and was acquainted with Lord Stanhope and the Duke of Bridgewater, the celebrated founder of the canal which is known by his name.

It was here that he was first induced to turn his attention to the improvement of navigation. He afterwards removed to Birmingham, and then to Paris, where he made many successful experiments in steam-navigation. He met with no encouragement, however, in France. He made an offer to Buonaparte, to provide steam-boats for the flotilla, with which he was about to invade England, but was rejected. In 1795, he published a treatise on Canals. He at length left France, finding he could not practise steam-navigation, owing to a patent that had been obtained by M. de Blanc, for steam-boats. He therefore returned to his native country, across the Atlantic; but here also the exclusive privilege had been granted in 1798 to Mr. Livingston, for navigating by steam all the waters in the state of New York. But an act was passed on the 5th of April, 1803, by which this right was extended to Mr. Fulton for twenty-one years. It had been granted, however, to Livingston, only on condition that he would, within two years, produce a steamer of twenty tons burden, that would run at the rate of four miles an hour. The time allowed for this purpose was afterwards extended to April, 1807. Livingston failed in accomplishing this, because he did not employ engines of sufficient power; but in 1807, Fulton finished his first American steam-boat, and worked it by means of an engine of twenty horse-power, sent over from England, from the manufactory of the celebrated Boulton and Watt. Fearing the expense might exceed his means, he offered one-third of his patent right to several gentlemen, on condition that they would contribute a similar portion of the expenses, but he could get no one to accept his offer before the experiment was made; though since that time so many have grasped at the profits derived from this invention of himself and his descendants. This boat afterwards plied regularly between New York and Albany, a distance of 120 miles, which was performed at an average rate of five miles an hour. The following account of its first voyage, extracted from Colden's life of Fulton, may be interesting.

"In the spring of 1807, the first Fulton boat built in America, was launched from the ship-yards of Charles Brown, on the East River. The engine from England was put on board of her; in August she was completed, and was moved by her machinery from her birth-place to the Jersey shore. Mr. Livingston and Mr. Fulton had invited many of their friends to witness the first trial. Nothing could exceed the surprise and admiration of all who witnessed the experiment. The minds of the most incredulous were changed in a few minutes; before the boat had made the progress of a quarter of a mile, the greatest unbeliever must have been converted. The man who, while he looked on the expensive machine thanked his stars that he had more wisdom than to waste his money in such idle schemes, changed the expression of his features as the boat moved from the wharf, and gained her speed: his complacent smile gradually stiffened into an expression of wonder: the jeers of the ignorant, who had neither sense nor feeling enough to repress their contemptuous ridicule and rude jokes, were silenced for the moment by a vulgar astonishment, which deprived them of the powers of utterance, till the triumph of genius extorted from the credulous multitude which crowded the shores, shouts and acclamations of congratulation and applause. This far-famed vessel, which was the *Clermont*, soon after sailed for Albany, and on her first voyage arrived at her destination without any accident. She excited the astonishment of the inhabitants of the shores of the Hudson, many of whom had never heard even of an engine, much less of a steam-boat. She was described by some, who had indistinctly seen her passing in the night, as a monster moving on the waters, defying the winds and tide, and breathing flame and smoke. She had the most terrific appearance from other vessels which were navigating the river, when she was making her passage. The first steam-boats, as others yet do, (*in America,*) used dry pine wood for fuel, which sends forth a column of flame, many feet above the flue; and whenever the fire is stirred, a galaxy of sparks fly off, which in the night have a brilliant and beautiful appearance. This uncommon light first attracted the attention of the crews of other vessels. Notwithstanding the wind and tide were adverse to its approach, they saw with astonishment that it was rapidly advancing towards them; and when it came so near that the noise of the machinery and the paddles was heard, the crews in some instances shrank beneath their decks, from the terrific sight; and others left their vessels, to go on shore; while others prostrated themselves, and besought Providence to protect them from the approach of the horrible monster, which was marching on the tides, and lighting its path by the fires which it vomited."

As soon as the great success of this attempt became known, steam-boats were rapidly built both in the old and new world. Since the time of Fulton, the practicability of steam-navigation has been placed beyond a doubt.

Almost every possible variation in the structure of the engines has been tried. The consumption of fuel has been greatly diminished; the speed attained by Fulton's first boat has been trebled. The sphere of steam-navigation has been extended from rivers and estuaries to the open sea. Steam-ships have not only become quite common in the seas and channels that surround our island, but have ventured out into the ocean, even in the most boisterous weather; and immense vessels, with engines of 300 horse-power, now ply regularly between Europe and America, across the stormy Atlantic. Our government has also highly patronized and encouraged steam-navigation, by constructing superb steamers, both for the purposes of commerce and warfare.

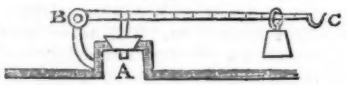
II. Before entering into the descriptive account of steam-navigation, it will be necessary to understand the general principles of the steam-engine, and also a few of the most important properties of steam.

Steam possesses, in common with all other aerial bodies, an expansive or elastic force, by which it always presses outwards, and endeavours to occupy a larger space. It is on this valuable quality of steam that the steam-engine acts. The force of steam or vapour increases according to its temperature. It always rises from water, and even from ice, at all temperatures; but boiling does not commence till the water attains the temperature of 212°, because it is not till then, that the steam becomes sufficiently elastic to overcome the pressure of the superincumbent atmosphere. Although air is an exceedingly light body, yet the atmosphere, or whole mass of air surrounding the earth, reaches so high above the ground, that it presses on every square inch of surface on the earth, with a pressure of 15 lbs. The steam therefore must also possess an expansive force of 15 lbs. per square inch, before it can rise from the water in the form of bubbles; and as steam or vapour below 212° does not possess such a power, water does not usually boil under that temperature. On the top of a high mountain, as there is less atmosphere above it, there is of course less pressure to be overcome, and water accordingly boils at a lower temperature. But at the bottom of a deep mine, there is the pressure of a greater height of air to be overcome, and therefore before the water can boil, the steam must have a greater expansive force, and to effect this, it must be raised to a higher temperature.

This proves that the force of steam or vapour depends upon its temperature, and that steam at 212° has an expansive force equal to the pressure of the atmosphere, or about 15 lbs. on every square inch of surface exposed to it. Steam of a higher temperature than this has a greater force than the air, or exerts a pressure of more than 15 lbs. on every square inch, and such steam is called high pressure steam. Low pressure steam has a pressure of less than 15 lbs. per square inch, and steam of a lower pressure than 212° is of this description.

But the expansive force of steam may be increased also by increasing its density or compactness, and this can be done by confining it in a close vessel, as a steam-engine boiler. The heat of the fire underneath causes steam to be continually given off by the water; but as it can find no outlet whereby to escape, it becomes compressed, its density or compactness is increased, and its tendency to expand is increased in proportion. Its expansive force is continually becoming greater and greater, and if this were continued too long, the boiler would be burst out, by the extreme tendency of the steam to occupy a larger space. To prevent this, an instrument called a safety-valve is used.

Fig. 1.



A small hole is made in the top of the boiler. Suppose A in the above figure to represent this hole. It is stopped air-tight by a valve or little lid, from which springs a stem, which is connected with a bar, B C, moving on a hinge at B. To the other end is hung a weight, by which the valve is pressed down; and it continues down so long as the elastic force of the steam does not exceed the pressure of this weight. But as soon as the force of the steam arrives at that pitch, it raises the valve, in spite of the weight, which it overcomes. A portion of steam then escapes, until the density of the remaining part is so reduced that it can no longer support the weight, and the valve falls. Thus, by placing different weights on the bar, the engineer or attendant can regulate the force of the steam in the boiler, and prevent it from exceeding that limit which is consistent with safety. But if the valve be loaded too much, it is no longer a safety-valve; for should the steam acquire a very great elasticity, it will burst the boiler, before it attains sufficient power to lift the valve. To prevent the inconvenience of having many different weights, the longer arm of the bar B C is usually graduated, and only one weight used, which is slid backwards and forwards to the different divisions on the bar, which then acts like a steelyard; for the same weight evidently possesses greater power, in proportion as it is situated at a greater distance from the fulcrum or hinge B.

The force, or pressure, or elasticity, of steam, is expressed by the number of pounds' pressure which it exerts on every square inch exposed to it. In high pressure steam, that number of pounds is of course more than fifteen, and in low pressure steam, less than fifteen. If the pressure be very high, it is expressed in atmospheres: thus steam of six atmospheres means steam having six times the pressure of the atmosphere, that is six times fifteen, or ninety pounds on every square inch.

Watt's condensing steam-engine, the principle of which is the same as that of nearly all the steam-engines now used, either for driving machinery, or for navigation, was an improvement on a former engine invented by Newcomen, which had better be first described. The chief part of this steam-engine, as of all others, was an iron cylinder, or upright round case or box, which in Newcomen's engine was open at the top. A tube coming from the boiler entered the bottom of the cylinder, and in this tube was a cock, which the attendant alternately opened and shut. In the cylinder was a piston, or solid flat kind of plug, fitting air-tight into the cylinder, but freely sliding up and down. When the above-mentioned cock was open, the steam rushed from the boiler up into the cylinder, pushing the piston up to the top. But the cock was then shut, and at the same time another cock in the side of the cylinder was opened. This cock was connected with a tube coming down from a cistern of cold water placed above, so that when this cock was opened, a jet of cold water was thrown into the cylinder. This instantly condensed the steam in the cylinder, and caused it to shrink into the form of water, in which form it occupied a very small space compared with its former bulk; which filled the whole cylinder. Thus a vacuum, or empty space, was formed beneath the piston, and the external air pressed the piston down with a pressure of about fifteen pounds per square inch. At the same time the last mentioned cock, (called the injection-cock,) was shut, and when the piston arrived at the bottom of its stroke, the first cock was re-opened, and another portion of steam rushed in from the boiler and pushed the piston up, and the former process was repeated. Thus the alternate opening and shutting of these two cocks, made the piston move up and down with immense force. To make this force available, the piston had attached to it a long rod, the upper end of which was attached to one end of a large beam, which was balanced in the middle like a see-saw. And to the other end of this beam was hung the rod of a pump for draining a mine. The engine also worked a smaller pump, by which the cold water cistern was kept always full. The two cocks were opened and shut, at first by hand, but afterwards by rods attached to the working-beam of the engine.

This form of engine had many great disadvantages, which it was the object of Watt to obviate. The principal defect was the enormous waste of heat caused by the alternate heating and cooling of the cylinder. During the down-stroke the cylinder was necessarily cooled, otherwise the steam would not be all condensed. When the steam entered from the boiler, therefore, the greater part of it was condensed and wasted; for the cylinder had to be first heated to a temperature as high as that of the steam, before the latter could raise the piston. To obviate this, Watt kept the cylinder always hot, and did not condense the steam in it, but drew it off into another separate vessel, in which it was condensed. Another defect was the cooling produced by the great mass of air which rushed down into the cylinder at every down stroke. To obviate this, Watt closed the top of the cylinder, and instead of forcing the piston down by the pressure of the air, he forced it down by steam introduced at the top; and during the up-stroke this steam was drawn off and condensed, as the steam below the piston had been during the down-stroke. This alternate admission of the steam, above and below the piston, is effected by an arrangement called a sliding-valve.

It consists of a box, from which branch four passages. One leads to the boiler, another down into the vessel in which the steam is condensed, another to the top of the cylinder, and the other to the bottom. The internal mechanism of this box is made in various ways. The following is one of the most simple.

Fig. 2.

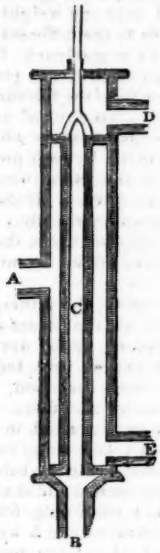
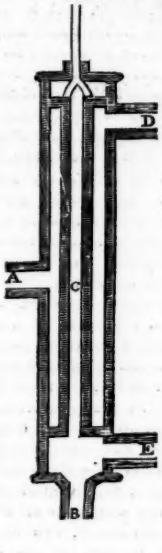


Fig. 3.

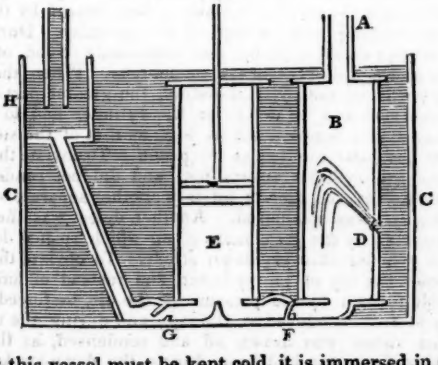


Each of these figures is a section of the valve-box, which is a large tube or cylinder, rather longer than the cylinder of the engine, with which it is connected, both at top and bottom. At A is the opening of the induction-pipe, or that by which the steam enters from the boiler, and at B, that of the eduction pipe, by which the steam is drawn off, after it has done its work. Within this box is a slider, C, which is a smaller tube, open at both ends, and having at each end a projecting rim or collar, fitting air-tight into the valve-box. This has a rod passing out at the top, and worked up and down by the engine.

When the slider is in the position shown in fig. 2, the steam, entering from the boiler at A, passes round on either side of the small tube, C, and escapes at E, into the bottom of the cylinder, forcing up the piston. At the same time, the steam above the piston is forced out through D into the valve-box, and descends by the eduction-pipe, B, into the condenser. But the slider C is now forced up into the position it has in fig. 3, in which the steam from the boiler goes to the top of the cylinder, by the passage D, forcing the piston down; and the steam below the piston comes out through E, and down through B into the condenser. The slider is then forced down again into the position of fig. 2, and another up-stroke is produced.

Let us now see what becomes of the steam after it has left the cylinder. It descends by the eduction-pipe, represented in the following figure by A, into a cylindrical vessel, B, called the condenser.

Fig. 4.

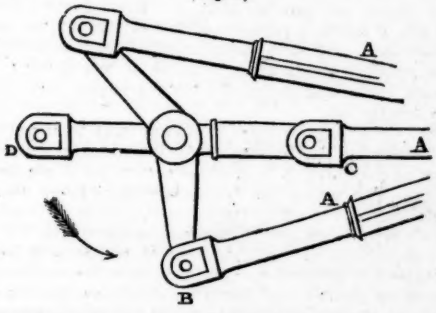


As this vessel must be kept cold, it is immersed in a cistern, C C, of cold water, and a jet of water is admitted by the cock D, called the injection-cock. The cistern is always kept full by a pump worked by the engine. When the steam descends into the condenser, the cold causes it to assume the form of water. In order that this hot water, together with the injection-water, should not accumulate in the condenser, it is drawn off by the air-pump E. This is generally constructed like a common pump, but the figure shows another simpler construction. Here, the air-pump has a solid piston, moved up and down by having its rod attached to the working-beam of the engine. At the bottom are two passages containing valves, both opening the same way. When the air-pump piston is drawn up, a vacuum is formed beneath it, and the mixed contents of the condenser open the valve F, and rush in to fill up the void. The air-pump piston is then forced down: the water, &c., below it, cannot escape by the valve F, because it opens only inwards, and therefore it is forced through the other valve G, and up the tube into a small cistern H, called the hot well. It is thence pumped up by another pump, to be returned into the boiler. The cold-water, air, and hot-water pumps are all worked by long rods attached to the working-beam, and from that end of the beam which is furthest from the cylinder hangs a strong rod or arm, working at its lower end a crank on the main axle which turns the machinery. These are the general principles of the steam-engine; but the various contrivances used to gain particular advantages, such as economy of fuel, labour, or attendance, are endless.

III. In marine engines, the principle remains the same; but it is obvious that great alterations must be made in the arrangement and situation of the different parts, that they may be fitted to propel a vessel, and that they may occupy as little room in that vessel as possible.

The mode used for propelling vessels by steam is, as it is well known, by floats or paddle-boards, which resemble in their action the wings of birds or the fins of fishes: they are moved backwards through the water, and the reaction of that fluid in a contrary direction pushes the ship forwards. The paddles are thus moved through the water by being fixed on the circumference of two paddle-wheels, connected by the main axle passing across the vessel; the object of the marine steam-engine is to turn this axle. This could evidently be done by a crank turned by the beam of a common engine, as described above, but it is found more convenient and compact to use a different arrangement. Two separate engines are generally made to exert their force together on two cranks on the main axle, and the chief reason of this is to obviate the great defect which one crank always possesses, which is this:—

Fig. 5.

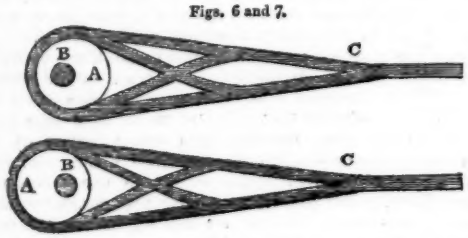


Let this figure represent a crank in different parts of its revolution moved by the crank-rod A: the only motion this rod possesses is backwards and forwards; the end of it has no tendency to describe a circle, but it is obliged to do so, because it is connected with a fixed centre. Now let the crank be at the position B, revolving in the direction indicated by the arrow: the rod pulls it to C; but when it arrives at that point, no mere pulling or pushing on the part of the rod can make the crank revolve, and it is carried past that point only by its own impetus; otherwise, the rod would have as much tendency to push it back to B as in the other direction. The same thing happens at the opposite point D, where no mere pulling would have any effect, were it not for the crank's momentum, or tendency always to revolve the same way. Thus the power with which the crank moves at the different parts of its course is very unequal; and there are two points C and D, called *dead points*, at which the power is almost nothing. In a stationary land-engine this irregularity is equalized by the fly-wheel. This is a large cast-iron wheel, with a very heavy rim, placed on the main axle, which prevents any sudden jolts or

variations in the velocity of the machinery; because the *inertia* of this heavy mass renders it very difficult either to set it in motion or to accelerate its motion, and when it has once been set going, its *momentum* renders it equally difficult to stop or retard it: hence, it possesses such a strong tendency not to alter its state or velocity, that all the little variations in the force of the engine are absorbed, and produce no sensible effect.

But such an arrangement would not be fitted for a marine engine. It is therefore dispensed with, and to serve in its place and equalize the motion, two cranks are worked, which are placed on the same axle, but at right angles to each other; so that when either of them arrives at one of its dead points C or D, the other must be at one of its strongest points, namely B, or the point opposite. Two engines are therefore employed, each moving a separate crank, and having a separate cylinder, beam, valve-box, condenser, and air-pump, but only one boiler; the beam is not placed above the engine as in land-engines, but each cylinder works two beams, placed below it, one on each side. The piston-rod has a cross-piece, or cross-head placed on the top of it, and from the two ends of this piece descend two rods, working the ends of the two beams up and down; the two beams are connected together at the other end by a bar, and from the middle of this bar rises the rod which works the crank on the main axle. One of the simplest forms of sliding valves has been already described; but it was not then stated by what means the slider was moved: this is generally done in steam-vessels by a contrivance called an *eccentric*. This is a small wheel placed on the main axle, and differing from ordinary wheels in not having the axle passing through it exactly in the centre; it is connected with a rod, as shown in the following figures.

Figs. 6 and 7.



A is the eccentric, B the main axle on which it is fixed, and C the eccentric rod, which terminates in a ring or loop which fits on the eccentric. If the axle of this wheel were in its centre, the rod would evidently remain stationary, but this not being the case, the eccentric has sometimes the position of fig. 6, and sometimes that of fig. 7; and thus the rod is moved backwards and forwards through a small space, and this motion is communicated sometimes directly, and sometimes by various levers, to the sliding-valve. The inner surface of the loop at the end of the rod, and the edge of the eccentric, are, of course, ground very smooth, and lubricated with grease or oil, as they are continually rubbing together.

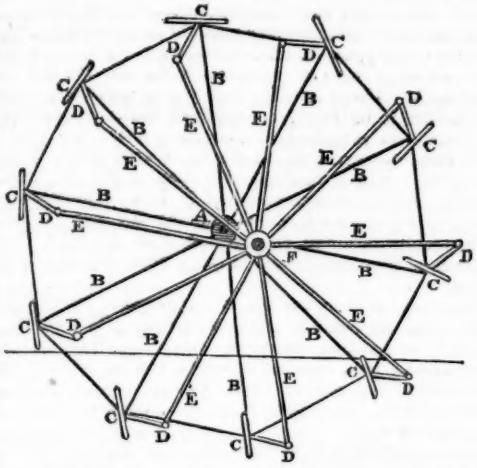
Fig. 8 is a longitudinal section, and fig. 9 a plan of that part of a steam-vessel which contains the boilers and engines, (see frontispiece.) The arrangement is the same as in the government steam-ship Phœnix, of 820 tons' burden, and 220 horse-power, divided between two engines. The letters on both figures are placed at the same parts; A A is the main axle bearing the paddle-wheels B B, to show which the paddle-boxes are removed. In the space occupied by the boilers and engines, the vessel is clear, and has no decks from top to bottom. C C C C are the boilers, which in different vessels vary greatly, both in form, number, and arrangement. In the Phœnix they are four in number, of a square or cubical form, and placed rather behind the main axle. In the plan are seen the fire-places placed along the front of the two front boilers: it has been attempted to place some or all of them behind, that they might be nearer the store of coal, but there was not a sufficient supply of air in that situation. The hot air and smoke circulate through the boilers by means of flues, which wind in various directions before they reach the chimney D: thus little heat is wasted. The four boilers are never used at once, one or two being always reserved to be ready in cases of accidents or repairs in the others. E is a reservoir of steam, on which are the safety-valves, of which there are now usually two, one of which has a moveable weight, so as to be regulated by the engineer. Thus he can regulate within certain limits the pressure of the steam, and so increase or diminish the power of the engines, and consequently the velocity of the vessel; or he can proportionate the power to the resistance of wind or tide to be overcome, which, of course, varies greatly at different times: but lest he should, through anxiety to increase the rapidity of the vessel, endanger it by overloading this safety-valve, another is provided inaccessible to him, being under a strong case firmly bolted down, but having holes for the escape of the steam. This has a fixed weight, so that the steam cannot exceed a certain pressure; for however much the other may be loaded, the steam will escape by this. F is the *waste-pipe* to conduct off the steam from the safety-valve, and G the main steam-pipe leading to the cylinders H H; each of which is enclosed in a case called a *steam-jacket*. The steam first enters the space between the cylinder and its jacket; and by thus surrounding the former keeps it constantly hot. The steam passes thence to the valve-box I, which is worked by rods as shown in the figure, connected with an eccentric K on the main axle; each engine having two separate eccentrics. But the direction of the motion of the eccentric-rod is backwards and forwards, while that of the sliding valve-rod must be up and down: this change is effected by a small sector L moving on a fixed centre at *l*, to one corner of which is attached the end of the eccentric-rod, and to the other that of the valve-rod. This sector is in its action like those used to change the direction of bell-wires. All the cast-iron framework of the engine is omitted in the figures to prevent confusion. M M in the plan are the cross-heads of the piston-rods, and N in the section is one of the rods by which the beams are worked. O O O O are the beams, only one of which is seen in the section; P is one of the crank-rods, and Q are the cranks at right angles to each other; the condenser is at R and the air-pump at S, in the tank of cold water; the piston of the air-pump is worked by the beams, by means of two rods attached to a cross-piece T, similar to that of the cylinder. The hot well is directly over the condenser, and is a high cylindrical vessel U, open at the top, but made very tall to prevent the water from being scattered by the motion of the ship. Besides the air-pump, which is, of course, always at work when the engines are, there are two others which are only occasionally worked; these are the bilge-pump and the feed-pump for supplying the boiler: they are placed one on each side of the air-pump, and their rods are connected with the beams by moveable bolts or screws, so as to be used only when required: they are not shown in the drawings. Of course, all this apparatus belongs to only one engine, and is therefore doubled on the other side, as seen in the plan; the paddle-wheels have each two bearings, one in the side of the vessel, and the other in the exterior part of the paddle-box. The axle of each wheel has in the Phœnix three small cast-iron wheels, seen at V V V in the plan; into these are fixed the wrought-iron arms or spokes W, each set of which is connected together by two rings at different distances from the centre, as seen in the section. Each paddle is made of a thick plank, and bolted to three corresponding spokes of the three wheels. As it is thought an advantage to throw the main axle and paddle-wheels more forward, the arrangement of the engines is exactly reversed in some vessels, the cylinder being placed behind, next the boilers. To compensate in some degree for the great projection of the paddle-boxes, the vessel is often contracted in width at that part, as seen in fig. 9.

In the common paddle-wheel, the planes of the paddles would, of course, meet in the axis of the wheel; and while they are passing through the water, they have their upper edge always directed to that axis. But it can be mathematically proved, that the effect would be greater, if their upper edges were directed to a point considerably above the wheel. Another defect is, the splashing and sudden shock on striking and entering the water. Now both these defects would obviously be diminished, if the paddles entered and left the water more vertically than they do at present. To effect this, the paddles must have another motion, independent of their rotation with the wheel; and an immense number of new wheels have been proposed for this purpose. But they are nearly all too complicated, and consequently liable to get out of order in the shocks of a rough sea; and there is but one which has been used to any extent. It is termed Morgan's wheel, though it was first invented and patented by Elijah Galloway in 1829; and afterwards improved by William Morgan.

It has been used with great advantage in many government steamers, and is represented in the following figure.

The wheel consists of two sets of arms or spokes, each revolving on a separate centre. A is the axle turned by the engine, and has fixed to it, the spokes B B, &c. The extremities of these are joined by straight bars, so as to form a compact polygonal wheel, at the corners of which are placed the paddles C C, &c., which are not fixed, but turn freely on an axis, as seen in the figure. At the back of each

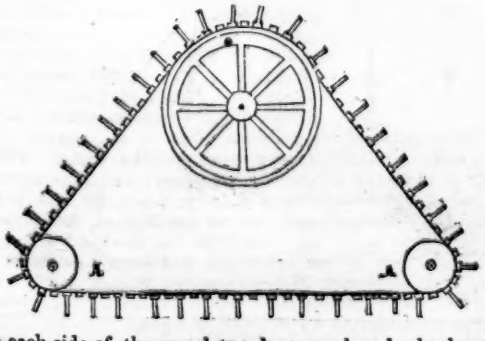
Fig. 10.



paddle is a short arm D, firmly fixed to the paddle at an angle of about 60° or 120°: to the ends of these arms, are connected by joints, the ends of the spokes E E, &c., which turn on a separate centre, F. Now as the wheel revolves, the distance between the points C or the axles of the paddles, and the centre A, is, of course, always the same. Therefore, their distance from the other centre F is always varying. But these two points C and F are always connected together by a jointed rod, consisting of the spoke E, and the short arm D; and to make up for the variation in the distance C F, the angle formed by the two rods D and E varies also. This angle is greatest when the point C is furthest from F, and smallest when those points are nearest to each other. Now as the arm D is firmly fixed to the back of the paddle, it cannot move without moving the paddle also. Thus, the paddle is always changing its position, as it moves round with the wheel; and if the distance and relative situation of the two centres, A and F, be properly adjusted, the paddles will remain nearly vertical during the whole of their passage through the water, and of course, their position when out of the water does not matter. In both the old and new wheels, the less the immersion, or the smaller the part of the wheel that is under water, the more vertically do the paddles enter and leave the water. But this difference is less in the new wheel than in the old, because the upper edges of the paddles are directed to a higher point. Hence the new wheel admits of a deeper immersion than the old, and the superiority of the former is most clearly perceived when both wheels are much immersed; while, when the immersion is small, the difference between the two wheels is hardly perceived.

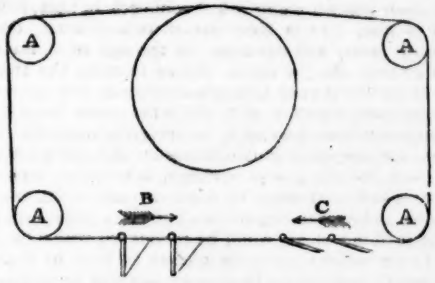
Another method which has frequently been proposed for obviating the defects of the common paddle-wheel, is to have

Fig. 11.



on each side of the vessel two drums or broad wheels, and to fix the paddle-boards to two or three endless chains, passing over these drums. If one or both of the wheels be then turned by the engine, the chains with the paddles will be drawn constantly in one direction through the water. Other methods of effecting this with only one large wheel, may be seen in figures 11 and 12, where A A are small pulleys over which the chain passes.

Fig. 12.



In the last of these is shown the mode in which the paddles must be fixed to the chains, when the large wheel is only moved half way round, so that the chain reciprocates backwards and forwards. If in this case the paddle-boards were firmly fixed at right angles to the chain, when the boards moved forward, the re-action of the water would push the ship back, and thus it would make no progress at all.

The paddles must therefore move on a hinge or joint, so that when they move in the direction of the arrow at B, the resistance of the water keeps them open, and they are kept at right angles to the great chain, by small chains, as seen in the figure; but when they are travelling in the opposite direction, the resistance of the water shuts them up as at C, and of course in that position they produce no effect.

None of these plans, however, have been found practicable, owing to the great friction and liability to get out of order.

But one of the greatest of modern improvements in steam-navigation, is the vibrating engine of Maudslay. It is one of the numerous contrivances to save space; which is, of course, one of the chief objects to be attained in marine engines. In this compact and beautiful arrangement the beams are altogether dispensed with. It might be thought possible to do this by placing the cylinders directly beneath the main axle, and connecting the upper ends of the piston-rods directly with the cranks: but the motion of the piston-rods must be exactly vertical; there cannot be the slightest deviation; otherwise they would fit loose, and not steam-tight, in their stuffing-boxes. But the rotatory motion of the crank would give them a motion backwards and forwards, and, therefore, cannot be applied in this manner, unless the cylinders be made to swing backwards and forwards also, so that the piston shall work parallel with the cylinder, although its upper end describes a circle with the crank. Now in Maudslay's engine this is done by suspending each cylinder on two bearings, or pivots, and allowing it to swing or oscillate like a pendulum. We cannot here, for want of space, enter into a detailed account of this admirable engine, but we will do so in an early number of the *Saturday Magazine*.

One of the greatest difficulties to be overcome in steam-navigation, and especially in long voyages, is the incrustation of salt, lime, and sometimes earth and sand, which accumulates in the boiler; for sea-water is of course used. None of the salts, or other ingredients contained in sea-water, rise in vapour with the steam; they all remain in the boiler, and thus accumulate till the portion of water contained in the boiler can no longer dissolve them, and they are deposited at the bottom and sides; in fact, if some method were not occasionally used to remove it, the boiler would soon become full, and choked with salt. The method commonly adopted is called "blowing out." At intervals, of from two to twenty-four hours, a quantity of hot water is allowed to flow from the boiler, and its place is supplied by water that has been pumped out of the condenser by the air-pump. Now it is obvious that the hot water allowed to escape, contains more salt than the natural sea-water; for its bulk has been diminished by evaporation, while the salt in it remains the same, none of it having been lost. But the water which is introduced in blowing out contains less than its natural portion of salt; for it is composed of the natural sea-water, used for injection water, mixed with the condensed steam, which is of course pure, having been distilled, and having left all its salt and impu-

rities behind in the boiler. By this process, therefore, a quantity of salt is got rid of, but there is also a great waste of fuel; for all the heat contained in the boiling water which has been blown out is wasted: and, after all, the defect is only partially remedied; for still the salt, &c., collects, sometimes in a hard crust, more than an inch thick, and so firm and hard that chisels are required to break it up and remove it, and even the tools are sometimes broken.

This incrustation being a bad conductor of heat, causes a waste of fuel, for the heat passes with difficulty through this thick crust, and the metal of the bottom of the boiler hence attains often a much higher temperature than the water above it; it even becomes sometimes red hot, having a temperature of 800° or 900°, while the water above it has a temperature of less than 300°; hence arises another evil, viz., the unnecessary wear of the boilers by this excessive heat.

In the present mode of working, it would be impossible to carry a sufficient store of fresh or pure water to supply the boiler and condensing cistern, and thus prevent incrustation; but if the steam could be condensed without a jet of condensing water, the water placed at first in the boiler would continually circulate through the engine, without any admixture with any other water, and with no waste except that lost by leakages: thus pure, or at least fresh water, could be always employed in the longest voyages, and with this there would be no incrustation. At the same time, as none of the water of the condensing cistern would enter the engine, that cistern could be kept always full of cold sea-water, which would answer as well as fresh water for the purpose of condensation. A method of condensing the steam without injection-water is, therefore, a great desideratum; and it has been effected by Mr. Samuel Hall, who has taken patents for various improvements in marine engines, but chiefly for a new kind of condenser, in which no jet is required. This condenser consists of a number of small upright tubes, uniting at the top in a flat vessel, into which the steam descends from the cylinder; and at the bottom there is a similar flat vessel, from which the condensed steam is drawn off by the air-pump. As these tubes are immersed in the cold water, the steam when it descends them is exposed to a great deal of cold surface, and is so perfectly condensed without a jet, that the vacuum is thought to be more perfect than that produced in the common condenser: the same water, therefore, continues always to circulate through the engine, so that pure water can be used. As the sea-water of the condensing cistern becomes warmed it is removed, and the cistern kept full by a supply of cold water constantly pumped into it by the engine.

Another great improvement, which bids fair to effect an immense saving of room and fuel, is the contrivance of Mr. Howard, by which the boiler is altogether dispensed with. Its place is supplied by a much smaller wrought-iron vessel, called a *generator*, which is placed over a coke-fire, and contains a quantity of mercury, covered by a very thin iron plate, on which a small quantity of water is thrown in at each stroke of the piston, by an injection-valve and tube communicating with a reservoir of water. The quantity of water thus thrown in, is only just sufficient to fill the cylinder, when vaporized, which it instantly is, because the temperature of the mercury is from 400° to 500°. For every horse-power in this engine, there ought to be about three-fourths of a square foot of surface exposed to the fire; so that for an engine of twenty-horse power, there should be about fifteen square feet of surface. This is the general principle of the improvement; but when all the minor alterations are attended to, the quantity of fuel used is said to be not more than one-third of that required for the common boilers.

In concluding the subject of Steam-navigation, and with it of Navigation generally, we would willingly, did space allow, refer in detail to the surprising achievements of the last year or two in steam-navigation. The details of ocean-steamers generally are, however, well-known; and we may further refer the reader to the fourth volume of the *Saturday Magazine*, p. 232, where he will find a view and description of a large American steamer. But even this vessel is exceeded in all its appointments by the Great Western steam-ship, which we may here briefly notice.

The Great Western steam-ship was constructed by order of a newly-formed Steam-Navigation Company; whose directors have spared no expense to render her a truly magnificent vessel, worthy of trading between two such great and powerful countries as England and America. She was built at Bristol. Mr. Patterson was the ship-builder: Messrs. Maudslay the engineers, and Mr. Brunel the consulting engineer.

The following are the dimensions of this vessel:—length 236 feet, breadth 58½ feet, and registered admeasurement 1340 tons. The floors are of great length, and overrun each other. They are firmly dowelled and bolted, first in pairs, and then together, by means of one-and-a-half inch bolts, about twenty-four feet in length, driven in four parallel rows, scarfing about four feet. She has stowage for 800 tons of coal, or coal and cargo combined, without encroaching upon her provision and water-room for three hundred people. Besides ample space for officers and crew, (comprising about sixty persons,) there are state-rooms, &c., for 128 first-class passengers. There are also twenty good secondary berths; and should it be found necessary or desirable hereafter to dispense with cargo-space altogether, about one hundred more sleeping-berths might easily be arranged. Such of her timbers as may be exposed to alternations of moisture and dryness, have been prepared by Kyan's process; and every effort has been made to combine the excellencies of naval architecture and engineering, with attention to the comforts of passengers, and to the general facility of quick travel.

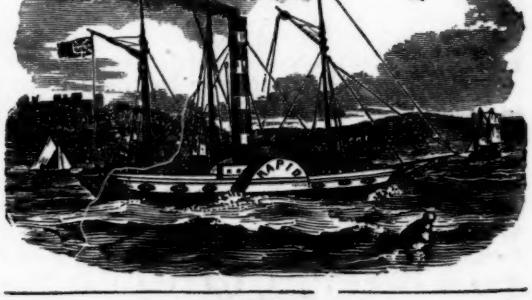
The steam-engines are the two largest that have yet been made: they are equal to 450 horse-power. The boilers, of which there are four, are so constructed as greatly to economize steam, fuel, and space: each can be worked independently of the others; while, by means of passages left between them, the engineer can cool, examine, or repair, those not in use.

The saloon of this superb vessel is, together with the other internal decorations, said to be in elegant taste. The length of the saloon is seventy-five feet; the breadth is twenty-one feet, exclusive of the recesses on each side, where the breadth is thirty-four feet; the height is nine feet clear of the beam; and fifty of the pannels are adorned with paintings by Mr. Parris.

The arrangement of the bells, from the various cabins to the steward's room, is new and ingenious. In this room are two small boxes, each containing a bell communicating by means of wires to every part of the vessel. When a passenger pulls the bell-rope, the bell in the small box rings, and at the same time, by means of a small lever, there is forced up through a slit in the box a tin label with the number of the room painted on it, where the services of the steward are required: the label so remains, until the steward has inspected it, and pushed it down again; so that, instead of having the noise and inconvenience of a vast number of bells, there are only two, and the sound of these is stifled by being enclosed in boxes.

Such, then, is a very brief description of one of the finest steam-vessels ever constructed.

We now close the subject of Navigation, which has occupied us thus far. If, in our progress, we should seem to have been too intent on describing the works of man and his progress over the waters of the globe, let not the reader fail to bear with us an humble tribute of gratitude and praise to that Great Power "who hath measured the waters in the hollow of his hand, and meted out heaven with the span, and comprehended the dust of the earth in a measure, and weighed the mountains in scales, and the hills in a balance."—Isaiah xl. 12.



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